February 17, 2003, Anatoly

Outline of Post Mortem study of Readout Modules (RMs).

Introduction

The RMs as part of CMS HCAL [1] readout system tested at CERN (H2 test beam area, summer 2002). The RM (fig.1) consists of aluminum shell, optical decoder unit (ODU, [2]), Hybrid Photodiode (HPD, [3]) with Interface Card (IC), High Voltage (HV) and Bias Voltage (BV) part, electronic compartment and optical output. Electronic compartment composed of 3 QIE [4] cards (6 channels per card), separated by cooling extrusion aluminum plates. Each QIE channel reads out through VCSEL [5] and optical link as output.

8 RMs were placed into 2 Hadronic Barrel (HB) Readout Boxes (RBXs, [6], fig.2), 4 RMs per box. Each RBX contains an aluminum shell with copper pipe for cooling water, high voltage and bias voltage distribution system, electrical backplane. Calibration Unit (CU) installed in RBX provides the light by LED (light emitting diode) illuminating each of 18 pixels of each HPD in calibration mode. 4 optical output connectors (18 optical fibers per connector) on the front face of the CU connected by 4 optical cables with optical input connectors of each RMs. The Clock Control Module (CCM) installed in each RBX serves to distribute clock (33 MHz for the test beam) to QIE of the RMs, also as to provide general control of the RBXs and communicate with the Slow Control System [7].

The 2 HB RBXs were installed on 2 barrel wedges of the HCAL. Light was delivered to the ODUs from megatiles by optical cables. ODU encoded the light into tower structure. Each single tower corresponds to single HPD pixel after the decoding.

Beam line

The H2 secondary beam allows to obtain pion, electron and muon beam in momentum range 20 – 300 GeV. Part of setup described earlier [8]. Moving Table (MT, [9]) was used to position each tower into beam. One of the new parts of the setup is a Data acquisition (DAQ) system for CMS HCAL [10].

The structure of the barrel allows to irradiate 16 towers in Eta direction and 6 towers in Phi in sequence. Each tower in Eta direction reads out by the same RM (each tower corresponds to single pixel).

Test beam observation

The average value (for whole Eta range) of the QIE counts for 225 GeV pions, 100 GeV positrons and 225 GeV muons are presented in fig. 3. The 8 kV of high voltage and 80 V bias were put on HPD for the each RM's. The average LED response for the RMs is also shown here. Note the LED light is sent to the separate RMs on separate cables. Also note that each RBX has a different CU. That means there are different CU for RM1 – RM 4, and RM5 – RM8. Figure 4 show the scatter plot for LED response and test beam data. It's clear observed different responses to LED for different calibration units. Presumably it is less amount of light for CU serving RM5 – RM8.

Fermilab and Minnesota measurements

2 RBXs/8RMs with the test beam DAQ were delivered to Fermilab for post mortem study. One CU LED output with the same optical cable (18 optical fibers) was fastened to each calibration optical input for each of 8 RMs in sequence. Again 8 kV of high voltage and 80 V bias applied to each HPD. The value of QIE counts with the same amount of light delivered to each pixel shown in fig. 5. Figure 6 present scatter plot for test beam data and LED response. One can observe correlation between test beam data and LED responses.

The next step was to understand the difference in responses for different RMs. According to Minnesota measurements stored in their database the gain of each HPD (8 kV, 80 V) is the same with about 3% percents of accuracy (RM1 – RM6). The HPDs serial numbers of the RMs are: RM1 – AZ0149188, RM2 – AZ0151002, RM3 – AZ0150076, RM4 – AZ0150075, RM5 – AZ0149187, RM6 – AZ0151003, RM7 – AZ0150077, RM8 – AZ0151299. The quantum efficiencies (QE) of the HPDs (the measurements were made for 500 V between photocathode and silicon) are shown in fig. 7. Spectral response (SR) of megatiles is also presented here. Convolution curves (CC) of SR and QE are shown in fig. 8. Test beam data also as the data normalized on plateau value of the CC are shown in figs. 9-11.

There is a change in QE as a function of applied HV. The actual HPDs used at the testbeam have not yet been measured for this effect. To get an estimate of the size of the effect, QE vs. HV for several other HPDs are shown in figs 12-14. An increase in the QE with HV is seen.

Additional tests

The responses of the RMs on magnitude of HV were taken with LED. Fig. 15 presents the data for the same pixel of each RM. All RMs show the threshold of response curve (about 3 – 3.4 kV) in agreement with HPD database except of RM 2. The measured threshold for the RM 2 is about 4.4 kV. The same results for different pixels of RM 2 and RM 3 are also presented for comparison (fig. 16). Several tests were made to understand this. 1 GOhm resistor in series with HV used in current HPD design. The responses were measured with the resistor and without it and show the same results (fig. 17). The value of the resistor was measured by voltage over current method and shows 1 GOhm resistance for that one. The value of HV was measured by electrostatic voltmeter directly on the output of HV distribution system and show again 8 kV kV of high voltage when it applied. The HPD of RM2 was replaced and the response of RM 2 was taken again (fig. 18). The measured threshold for the new HPD is in good agreement with the HPD database. The test beam HPD of RM 2 continue to be under investigation.

Conclusion

We can conclude now the variation of test beam responses for different RMs is mainly due to the HPD quantum efficiency variation. The RMs responses obtained on the beam are in good agreement with LED responses (figs. 6 a, b, c) despite on the fact that blue LED used in the measurements. Nevertheless green LED will be installed in the next version of CU for better HPD tracing.

Correction for QE variation causes the RMs (except RM2) to have approximately the same response to pions, positrons, muons as shown in figs. 9, 10, 11.

The only mystery remaining is RM2. A new HPD put into RM2 shows response expected from Minnesota database (new HPD serial number is AZ0201048). Minnesota test of the HPD from RM2 did not show the unusually high threshold (4.4 kV according to FNAL measurements). Our plan to get that HPD back, reinstall into RM2 and proceed from there.

References

1. **CMS Hadron Calorimeter Technical Design Report, CERN/LHCC 97-31, June 20,1997**
2. **Electro – Optical Readout System for the CMS Scintillating Hadronic Calorimeters IX International Conference on Calorimetry in Particle Physics, Annecy, France, Oct., 2000. Published as D. Karmgaard et al. Frascati Physics Series 21, pp. 189 – 198, B. Aubert et al., ed. 2001.**
3. **Hybrid photodiode (HPD), Delpht Electronic Production catalog.**
4. **T. Zimmerman et al., "Specification for Production CMS QIE ASIC (QIE8)", Revised September 27, 2002.**
5. **VCSEL, Honeywell's HFE4191-541.**
6. **J. Marchant et al., "Electro – Optical Interface Design for CMS HCAL", NSS/IEEE 2002 Conference.**
7. **D. Lasic et al., CMS HCAL Detector Overview", October 2000.**
8. **V. Abramov et al., "Studies of response of the prototype CMS hadron calorimeter, including magnetic field effects, to pion, electron and muon beam", NIM, A 457 (2001) pp. 75 – 100.**
9. **Moving Table.**
10. **CMS DAQ.**

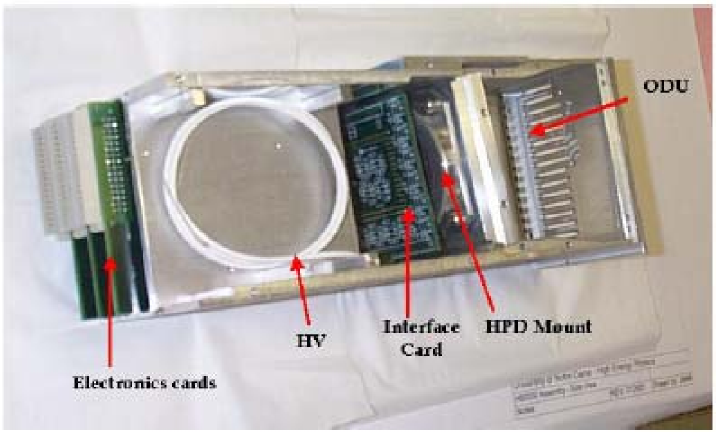

Fig. 1. RMs parts

Fig. 2RBXs parts.

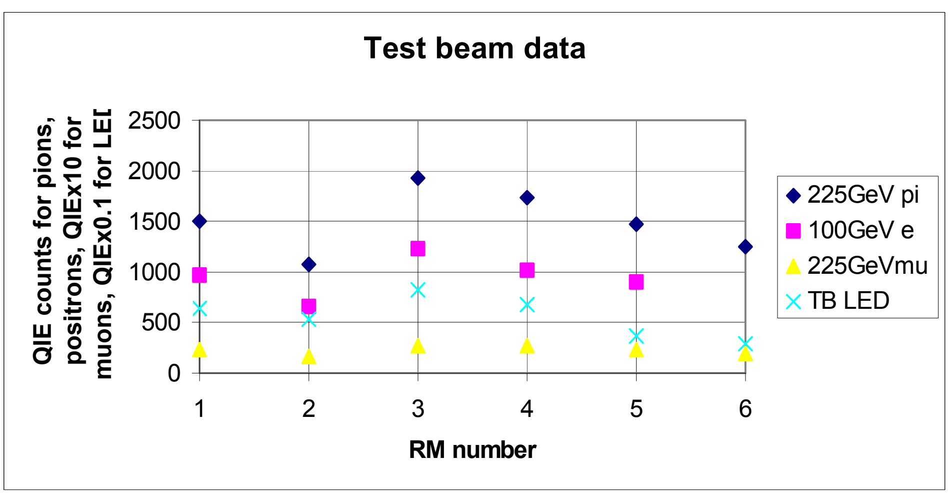

Fig. 3. Test beam data

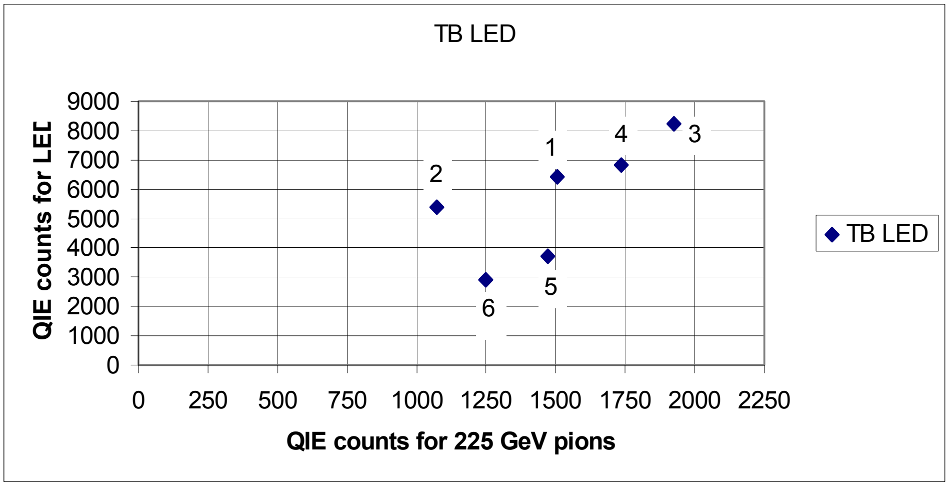

Fig. 4a. QIE counts for LED vs.QIE counts for 225 GeV pions. RM number marked close to measured point.

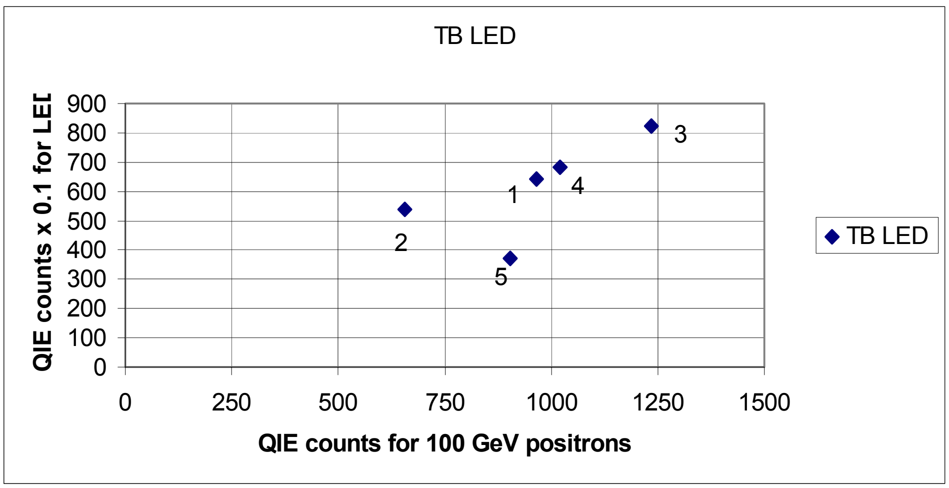

Fig. 4b. QIE counts for LED vs. QIE counts for 100 GeV positrons.

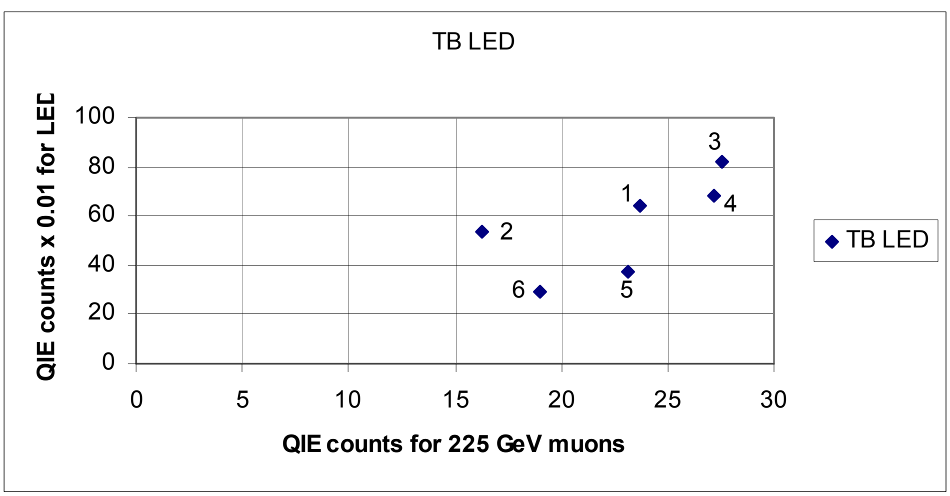

Fig. 4 c. QIE counts for LED vs. QIE counts for 225 GeV muons.

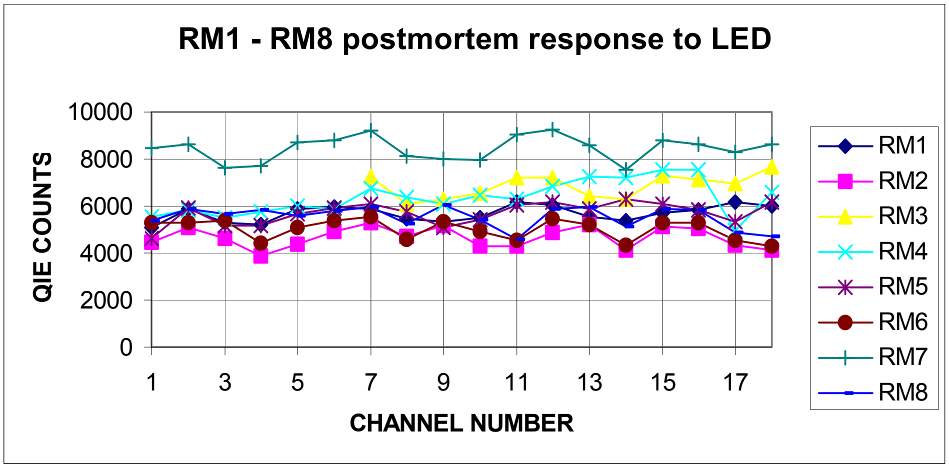

Fig. 5. QIE response to the same mount of light delivered to each pixel of RM1 – RM8.

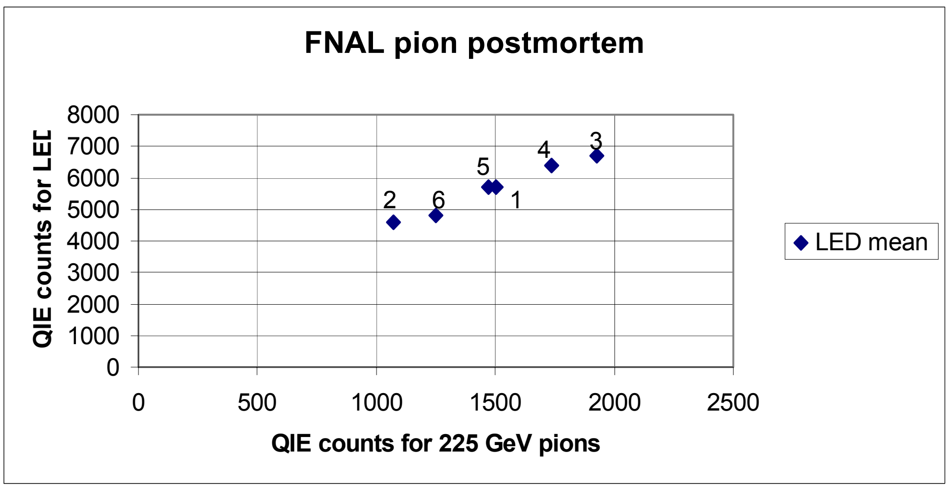

Fig. 6 a. QIE counts for mean LED vs. 225 GeV pions.

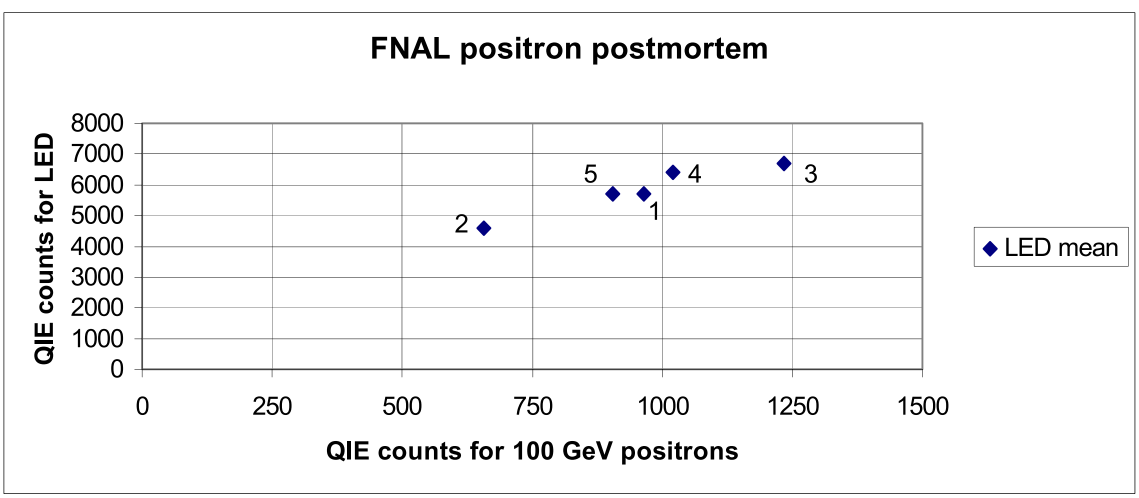

Fig. 6 b. QIE counts for mean LED vs. 100 GeV positrons.

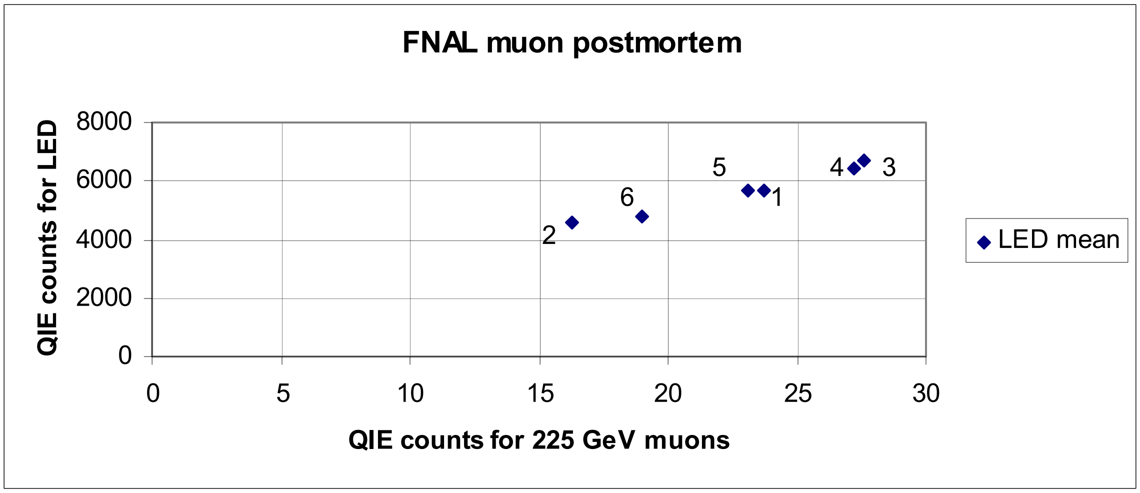

Fig. 6 c. QIE counts for mean LED vs. 225 GeV muons.

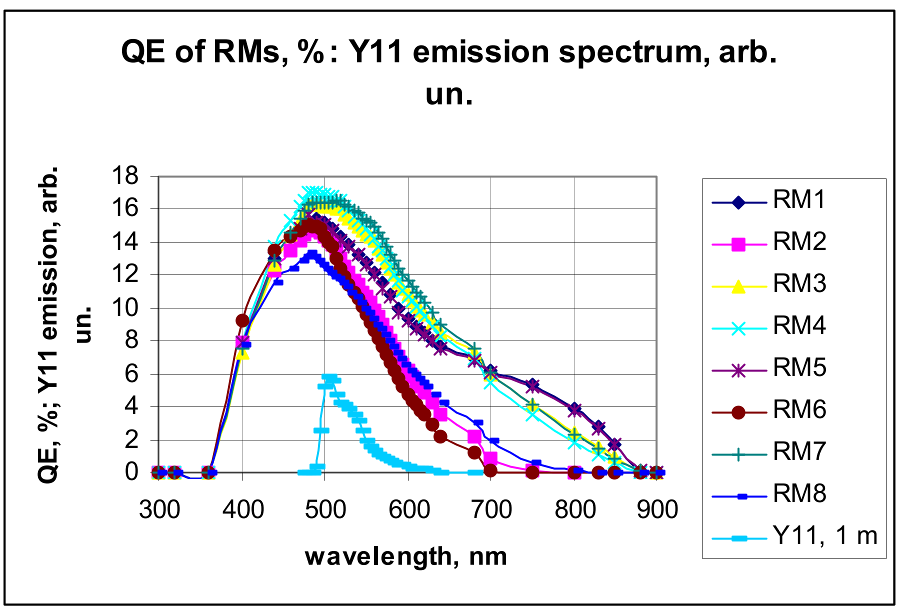

Fig. 7. Quantum efficiency (QE) of HPDs in RMs, Y11 emission spectrum.

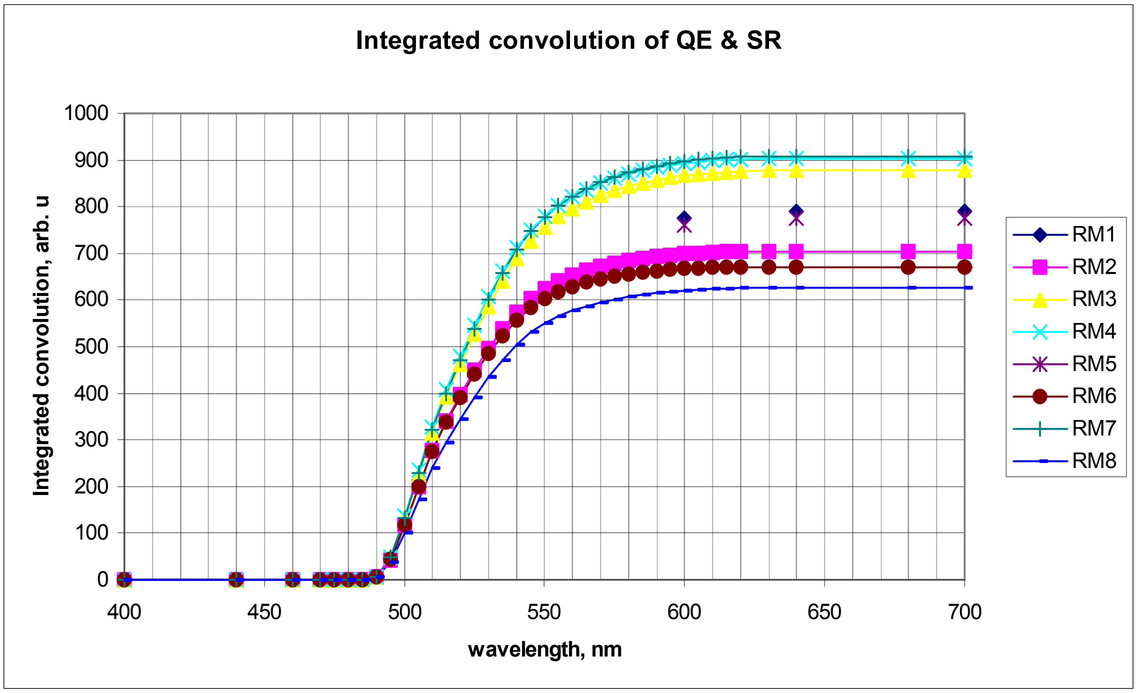

Fig. 8. Convolution curves of megatiles spectral response (SR) and quantum efficiency of HPDs.

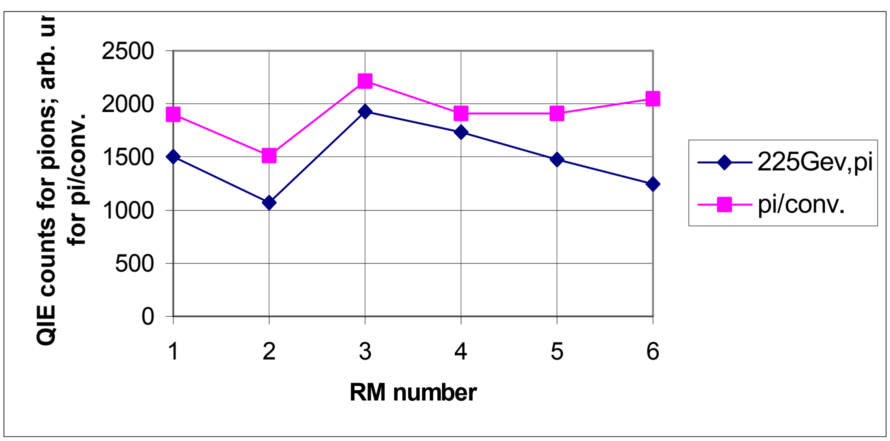

Fig. 9. RMs responses to 225 GeV pions also as the response corrected on convolution value.

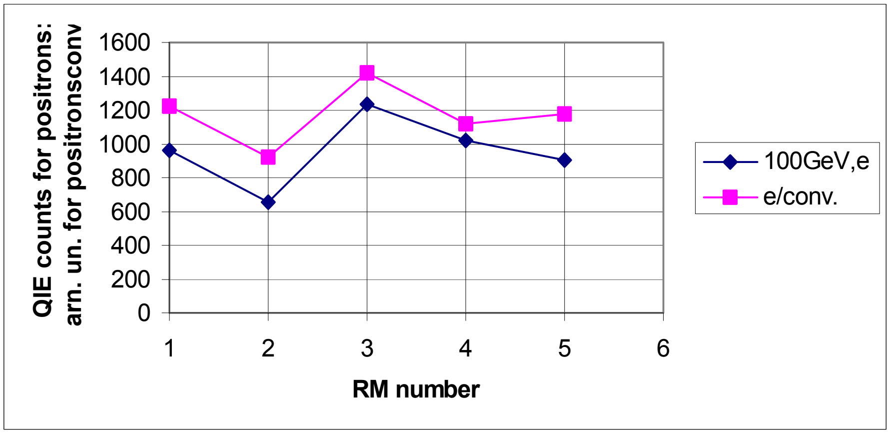

Fig. 10. RMs responses to 100 GeV positrons also as the response corrected on convolution value.

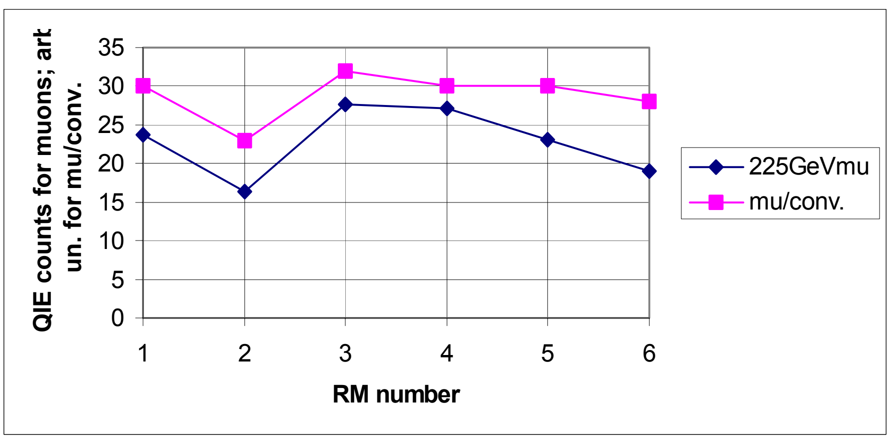

Fig. 11. RMs responses to 225 GeV muons also as the response corrected on convolution value.

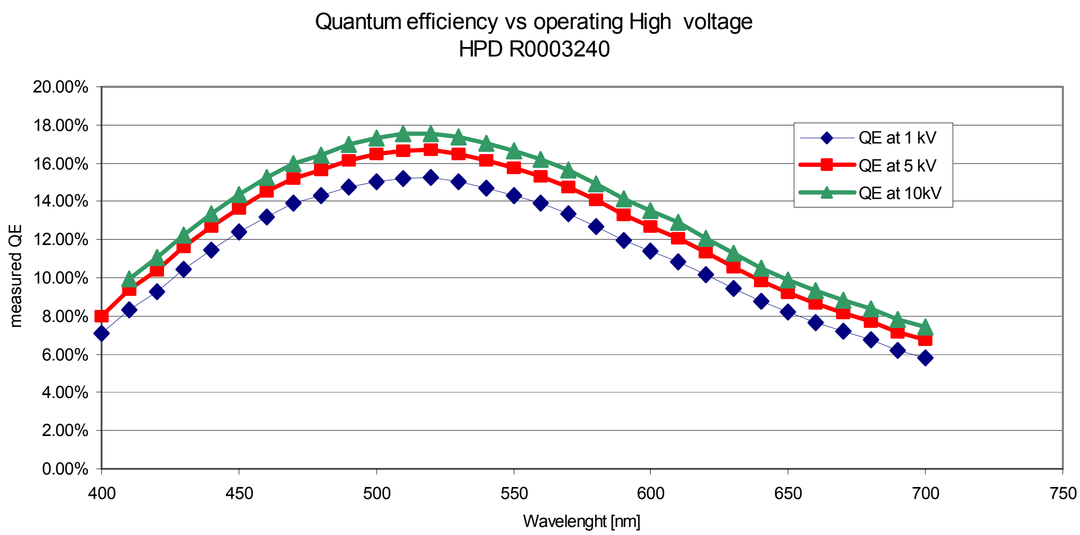

Fig. 12.

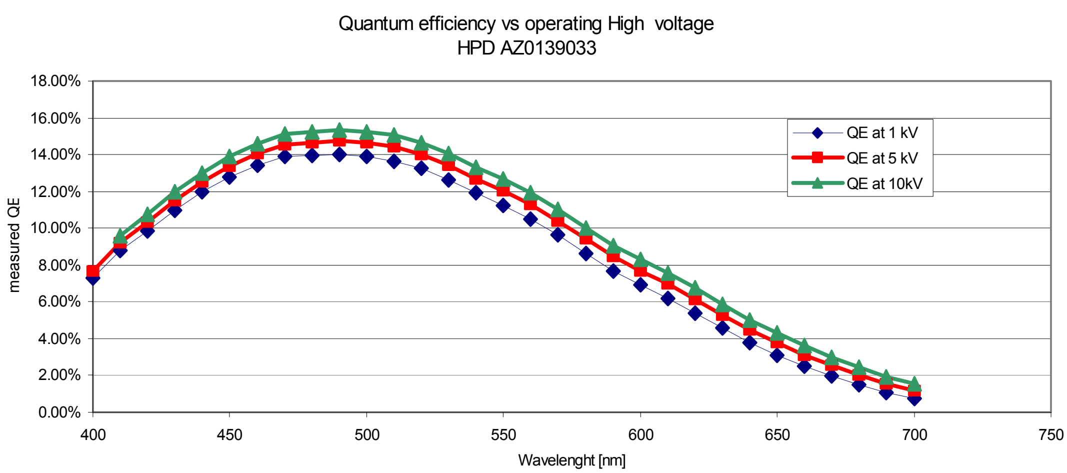

Fig. 13.

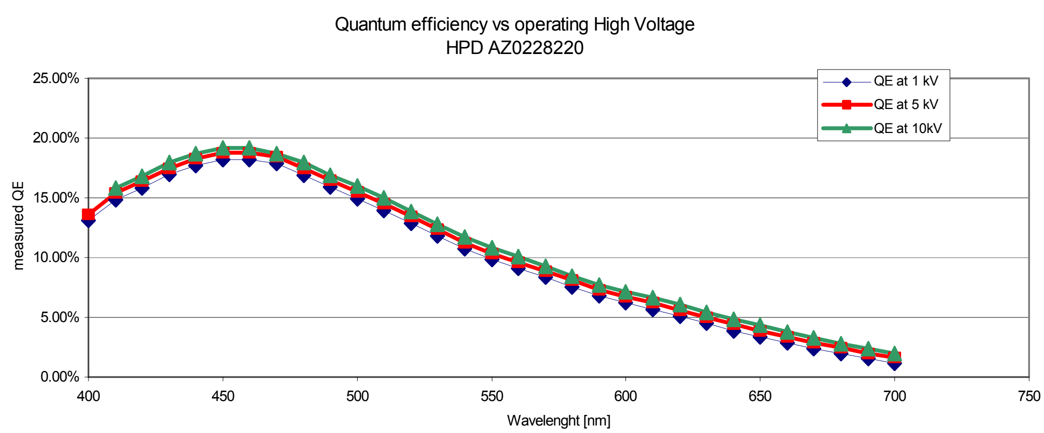

Fig. 14.

Figs. 12, 13, 15. QE vs. HV for different (not test beam) HPDs.

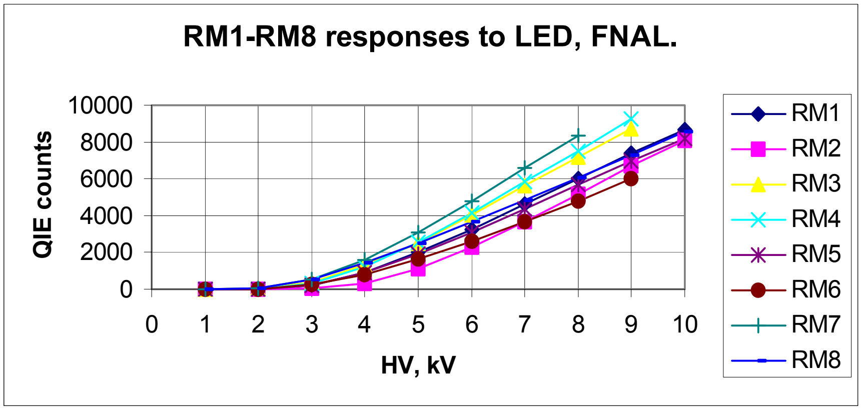

Fig. 15. LED response dependence on HV for the same pixel number for RM1-RM8.

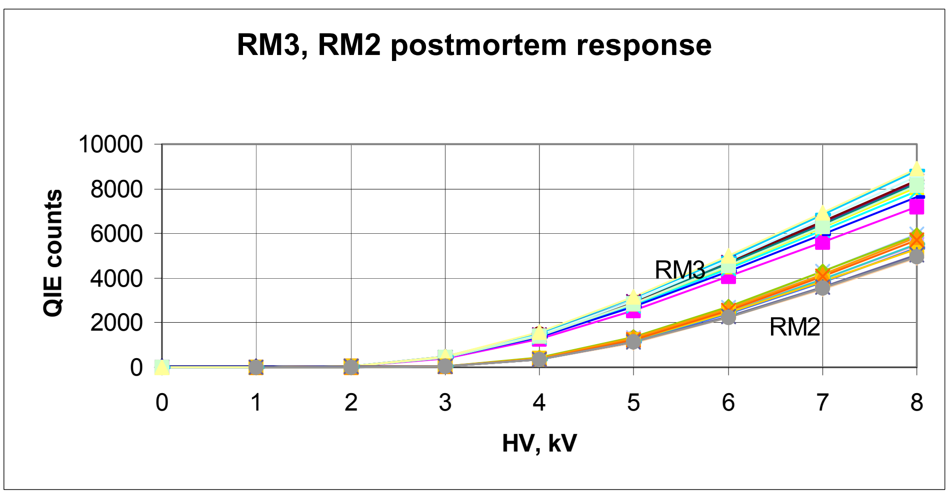

Fig. 16. RM2, RM3 (different pixels) responses to LED versus high voltage magnitude.

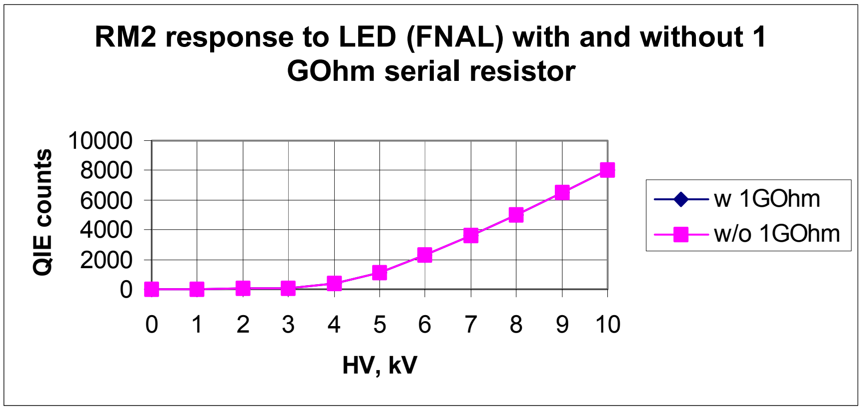

Fig. 17. Response RM2 to LED versus HV with and without 1 GOhm serial resistor.

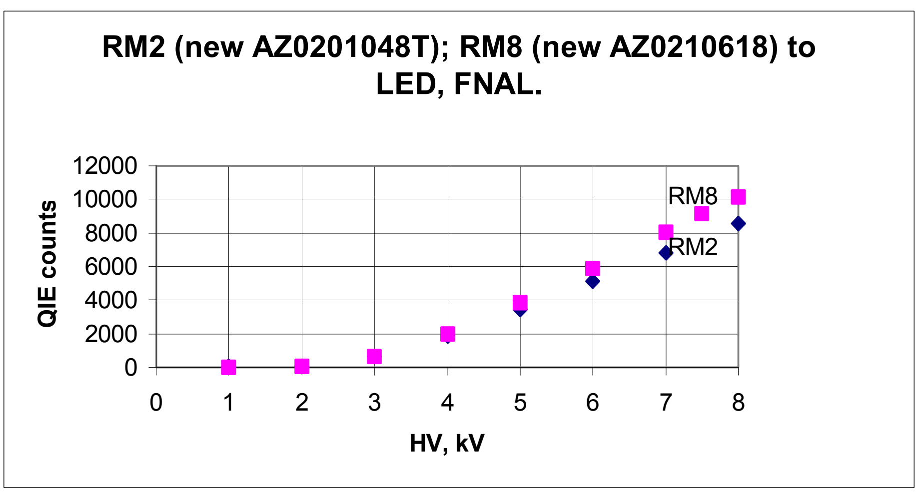

Fig. 18. RM2 and RM8 responses for not test beam HPDs.